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ENERGY EXPENDITURES *of* Women Performing Selected Activities

Home Economics Research Report No. 11

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

The research reported here provides a basis for designing efficient work areas in the home and for developing energy-saving work methods. These designs and methods make it possible for homemakers with certain physical limitations to care for their homes dispite their disabilities and for normal homemakers to participate more extensively in activities in the home and community.

The authors express their appreciation to E. James Koch, Biometrical Services, for advice in developing the statistical designs, and to Lenore Sater Thye, Clothing and Housing Research Division, Agricultural Research Service, for invaluable assistance in formulating, initiating, and promoting the project in general, and for continued interest and personal encouragement in all of its specific phases; also to Dr. J. A. Scharffenberg, National Institutes of Health, Bethesda, Md., for taking the anthropometric measurements.

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ENERGY EXPENDITURES *of* Women Performing Selected Activities

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SUMMARY

The relative energy requirements of women at rest and performing elemental activities were studied to develop energy-saving methods connected with routine household operations.

Measurements of energy expenditure were made with the subjects lying, sitting, and standing; walking with 90-degree and 180-degree turns; walking while carrying an 18-pound load and while pulling the load on a cart; and bending with trunk- and knee-bends. In one phase of the study, the factorial method of determining energy expenditures was compared with the continuous-measurement method.

Sitting required 10.2 percent more energy than lying; standing required 16.2 percent more than lying and 5.6 percent more than sitting. These increases were highly significant. Energy expenditure values for a given activity varied considerably between women tested, for each individual subject, and with the time of day.

When the women walked at their own natural stepping rate, which averaged 119 steps per minute, and at controlled rates of 96, 108, and 120 steps per minute, the energy (Cal./min.) they expended was in a highly significant linear relationship ($r=0.58$) to the speed of walking (km./hr.).

Expressed in Calories per hour, energy expenditures for walking at 108 and 120 steps per minute were 3.9 and 12.9 percent larger, respectively, than those for walking at 96 steps per minute. The differences in expenditures among these three controlled rates were highly significant. For the group, energy expenditures for their own stepping rates, which ranged from 107 to 131 steps per minute, did not vary significantly from those at the 120-steps-per-minute rate.

In terms of horizontal distance covered, expenditures were significantly greater for walking at the 96-steps-per-minute rate than at the 108- or 120-steps-per-minute rate. Mean expenditures were 62.6, 56.5, and 54.1 Calories per mile, respectively. Calculated on the basis of body weight, mean expenditures were 0.62 gram calories per kilogrammeter while the women were walking at 96 steps per minute (2.2 miles per hour) and were 0.57 and 0.53 gram calories, respectively, at 108 and 120 steps per minute (2.6 and 2.9 miles per hour). The number of steps taken to cover the test distance had a highly significant negative correlation with speed in kilometers per hour ($r=0.73$). No significant correlation was found between leg length or body weight and the energy expenditure for walking.

Walking at 96 steps per minute with turns of 90 and 180 degrees each 10 feet required, respectively, 16 and 18 percent more energy than walking in a straight line. These differences were highly significant. The difference in expenditures between 90-degree and 180-degree turns was not significant when walking at this rate.

Energy expenditures for walking while carrying an 18-pound load and while pulling the load on a four-wheeled cart were not significantly different, but were significantly greater than those for walking at the same rate without a load. The increases were 81 and 69 percent, respectively.

Knee-bending required a highly significant 29 percent more energy than trunk-bending in terms of Calories per hour. On the basis of Calories per procedure, in which individual variations in rate of work were eliminated, the increase in energy expenditures of knee-bending over trunk-bending was 43 percent, which was highly significant. Energy expenditures in Calories per hour were 163 and 240 percent higher for trunk- and knee-bending, respectively, than for standing at rest. These differences were also highly significant.

Continuous measurement of the energy cost of an activity was comparable with factorial measurement, in which total cost was obtained by adding energy expenditure values for each component part of the activities studied. This was true even when the energy cost of the activity had been obtained after various conditions of previous action.

Anthropometric measurements of the subjects were considered in relation to energy expenditures for selected activities. The largest correlation ($r=0.65$) was found between leg length and energy expended in walking while carrying an 18-pound

load at a rate of 120 steps per minute. No significant correlations were found between the anthropometric measurements made and energy costs of the activities studied.

Relationships of shoulder height, elbow height, and crotch height with stature showed significant correlation coefficients of 0.93, 0.73, and 0.67, respectively. The correlations of other measurements with stature were rough and not significant.

Basal metabolic rate determinations, along with age, height, and weight are reported for 68 candidates from whom the subjects for this study were selected.

PURPOSE AND SCOPE OF THE STUDY

Conservation of energy in the performance of household tasks is of special importance to the physically handicapped homemaker who, notwithstanding her disability, must take care of her home and family. To the healthy homemaker, the saving of energy in routine housework may enable her to participate more extensively in activities in the home and community.

To develop energy-saving methods for the use of homemakers in performing household tasks, the relative energy expenditures of carrying on specific activities by different methods must be known.

Few physical data for women exist that can be used as a basis for designing homemaking equipment and work areas, and for developing efficient work methods. A study was therefore undertaken to compare the relative energy expenditures of women when at rest in various positions—lying, sitting, and standing—and when performing various elemental activities—walking in a straight line at different rates of stepping, walking with turns, walking while carrying or pulling an 18-pound load, and bending with trunk- and knee-bends.

Results of such a study should contribute to the growing knowledge of the physiological responses of women to basic body positions and selected activities.

The continuous-measurement method of determining energy expenditures was compared with a factorial method, in which expenditures were obtained from separate determinations of component parts of an activity.

Anthropometric measurements were taken for an investigation of their possible relation to energy expenditures.

Nine women who participated in the phases of the study reported here were chosen from 68 candidates on the basis of predetermined limits for height, weight, and basal metabolic rate.

Findings are part of a more comprehensive study. Two phases of the research have already been published: The first (*36*),[1] in which energy expenditures were determined for women using built-in ovens at different elevations, and the second (*37*), in which energy expenditures were determined as criteria for the design of household-storage facilities.

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[1] Numbers in parentheses refer to Literature Cited, p.18.

EQUIPMENT AND GENERAL PROCEDURES

For the basal metabolic rate determinations, oxygen consumption was measured in a closed circuit apparatus (*39*). In the activity tests, energy expenditures were determined from measurements of total pulmonary ventilation and the oxygen content of the expired air, by means of instruments as described below.

Instrumentation for the Activity Tests

Until recently, measuring the energy costs of household activities has been difficult because of cumbersome equipment. Lavoisier suggested that indexes for the estimation of energy expenditure could be obtained from the products of oxidation, the amount of oxygen consumed, or the rate of loss of heat from the body. Since that time, interest in this advancing knowledge has been keen; the literature, voluminous. An excellent history of developments and review of experimental methods is given by Douglas (*17*).

Respiration chambers are suitable for experiments of long duration, but are costly and inadequate for studying many types of activity. In experiments of short duration, human energy expenditure can be measured less expensively and more easily by the indirect method. The Douglas bag (*16*), which has been widely used for the collection of expired air, is reliable but limits the time and the extent of measurement.

Researchers have long desired improved apparatus and methods that would permit studies of human energy expenditure "to be undertaken on an expanded scale inside and outside the laboratory" (*27*). In 1940 Kofranyi and Michaelis (*31*), of the Max-Planck Institut für Arbeitsphysiologie, developed a device that overcame many of the limitations imposed by earlier types of apparatus. This instrument, later improved by Müller and Franz (*43*), now offers a relatively convenient and inexpensive indirect method for obtaining simultaneously figures for total pulmonary ventilation and samples of expired air.

A respirometer of the Müller-Franz type was used in the study reported here. The instrument consists essentially of a small gas meter that measures the total volume of air exhaled by the subject; the air flows to the meter through a breathing valve and bellows tube. The meter, with an accuracy of ±1.0 percent for volume, measures flows up to 60 liters per minute. An odometer-type counter, which can be read accurately to 0.1 liter, indicates the total volume of exhaled air. Since the meter calibration cannot be adjusted, a gage (correction) factor is needed for each instrument.

The respirometer, as ordinarily constructed, can be adjusted to collect either 0.3 or 0.6 percent of the total expired air. The aliquot part of the measured expired air is bypassed by means of a piston pump to a collecting tube to which a sampling bag is attached. The rest of the expired air is exhausted into the atmosphere through small openings in the respirometer. Determinations can be made over long periods because of the small fraction of the expired air collected. The use of a collection bag the size of a basketball bladder extends the measuring period beyond that required for most household tasks.

The meter with the collection bag and all other accessories weighs less than 8 pounds. The meter may be worn by the subjects or may be set close by on a chair, a table, or on the floor. During locomotion, another person can carry the meter, in which case it is connected to the subject by an extended piece of tubing. The apparatus is supported by an adjustable harness, so that it can be adapted for different subjects and activities. Normal body movements of the subjects are not hampered by the equipment.

The subjects needed little instruction in the use of the respirometer and quickly became accustomed to wearing it. Accumulation of saliva in the mouthpiece during the more strenuous activities, particularly those involving stooping, interfered with the action of leaflets in the respiratory valves. The use of ordinary No. 2 cotton rolls, either full length (1½ inches) or cut in half, helped to solve the problem. In other tests, frequent swallowing usually prevented excessive accumulation of saliva.

For analyzing the expired air, the time-consuming Haldane apparatus was formerly used. However, Insull and coworkers (*27*) have shown that for analyzing oxygen concentrations, the electronic method is as satisfactory as the chemical Haldane method. Therefore, a Pauling-type (*47*) electronic analyzer manufactured by Beckman (*2*) was used. This instrument determines the oxygen partial pressure of an air sample by measuring the magnetic susceptibility of the gas with a magnetic torsion balance. Since oxygen is relatively paramagnetic, accurate oxygen analyses can be made in the presence of practically all gases.

After the expired air sample had been analyzed for the percentage of oxygen, energy expenditure was computed by a formula developed by Weir (*55*) for determining the metabolic rate as a function of pulmonary ventilation and oxygen content. Weir formulas are based on the volume and oxygen content of expired air and are specific for known proportions of protein Calories [2] in the diet. If the formulas are to be used for the determination of absolute energy expenditure values, the percentage of protein in the subjects' diets must be known.

However, a Weir formula involving 10-percent protein gave results only 0.38 percent lower than the formula for 15-percent protein. Since only relative values were of chief concern in this study, it was deemed unnecessary to determine the percentage of protein in the diets. On the basis of available dietary data, it was assumed that the protein intakes of the subjects would fall within a range of 10 to 15 percent of the total Calories in their diets, and the Weir formula for 10-percent protein was used in calculating the total energy expenditures of the subjects.

Selection of Subjects

The following general physical requirements were established for the selection of the subjects:

A height range of 5 feet 2 inches to 5 feet 5 inches to encompass the values given in various tables for the average height of women in the United States (*40*, *44*, *48*).

A weight range of 110 to 160 pounds to preclude more variable results that might be obtained for those outside this range who might have difficulty performing the more strenuous tasks.

A basal metabolic rate, without medication, ranging from −15 to +15 percent according to the Aub-DuBois Standard as modified by Boothby and Sandiford (*7*) to eliminate subjects whose energy expenditures might be considered "abnormal." In order to obtain subjects meeting these requirements, the metabolic rates of 68 presumably "normal" women were determined. These rates and other data obtained on all these women are presented and discussed in the appendix (p. 21).

General Procedures for Activity Tests

Sequences for activity testing were composed of the following parts: (1) A preactivity test during which the subjects sat or stood quietly; (2) activity tests; and (3) a postactivity test of sitting or standing quietly. Each activity test was kept reasonably short—from 1 to 5 minutes. Experimental periods were alternated with rest periods of lying quietly for at least 20 minutes. For activities requiring relatively high energy expenditures, intermediate rest periods of measured duration were incorporated between activities in order to minimize any effect of oxygen debt.

Blood pressure and body temperature measurements were taken during the first rest periods in the morning and afternoon. Pulse-rate measurements were started within 10 seconds after the completion of the work periods. Body weight was recorded daily.

Two subjects worked in the laboratory each day, and each subject performed five or six sequences daily.

Each woman wore a lightweight, comfortable dress that did not restrict body movements, and the same low-heeled shoes for all tests. Before the subjects participated in any tests, they practiced wearing the respirometer until they became accustomed to it.

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[2] The Calorie (spelled with a capital C) is the amount of heat necessary to raise the temperature of 1 kilogram (1,000 grams) of water 1 degree centigrade. In this report this unit is used to express energy values of foods.

Statistical Treatment

Each phase of the study had its own particular statistical design and treatment. Factorial experiments in randomized complete blocks, Latin squares, and square lattice designs (*13*) were used, because they permitted simultaneous investigation of numerous factors, with minimum replications and error. The order of performance of activities in a series and the time of day of testing were always selected at random.

Statistical analysis of variance was performed according to the method of least squares (*53*). Tests for significance were made according to the Student's t-test (*53*), and means were compared by the Duncan multiple range test (*20*).

Correlation coefficients were calculated to relate energy expenditures with certain anthropometric measurements and weight.

SPECIAL PROCEDURES AND RESULTS

Lying, Sitting, and Standing

Energy expenditures of individuals at rest have been reported by Rubner, Zuntz, Atwater, Benedict, Lusk, and Carpenter. More recently, Orr and Leitch in 1937 (*45*) and Passmore and Durnin in 1955 (*46*) made comprehensive reviews of energy expenditures of individuals at rest and in typical occupations. Studies were reported by Edholm and coworkers in 1955 (*22*) and by Booyens and McCance in 1957 (*8*).

In the current study, energy expenditures when lying, sitting, and standing quietly were determined for six women (identified as subjects 20, 31, 43, 44, 45, and 54, table 15). Means for their height, weight, age, and basal metabolic rate at the beginning of the study were 63.9 inches, 139.4 pounds, 38 years, and −7 percent, respectively.

Measurements were made in test sequences composed of two lying, sitting, and standing periods of 5 and 10 minutes. A total of 132 tests was accomplished for each body position. Lying tests were always performed first in the sequence, but the order of sitting and standing tests was randomized to minimize differences attributable to the specific dynamic action of food or any possible oxygen debt. Between sequences the subjects rested lying down for at least 20 minutes.

Every attempt was made to prevent tension in the subjects during the tests, as well as to eliminate extraneous motion and psychological disturbances. They sat in a straight office-type chair with arms and rested their feet flat on a surface of wooden blocks adjusted to their comfort. For all tests the respirometer was placed on a table beside the subject.

For these subjects, the mean energy expenditure values for lying, sitting, and standing were 56.8, 62.6, and 65.9 Calories per hour, respectively, or 34.1, 37.6, and 39.7 Calories per hour per square meter of body surface (table 1). The differences were highly significant.[3]

Sitting required 10.2 percent more energy than lying; standing required 5.6 percent more than sitting and 16.2 percent more than lying (fig. 1). The 5.6-percent increase for standing over sitting is lower than the 7.1-percent increase from the compilations by Brown in 1952 (*12*) and the 12.4-percent increase reported by Booyens and McCance in 1957 (*8*), but higher than the 4.9-percent increase as compiled by Sherman in 1952 (*51*).

In table 2 the mean values found for lying, sitting, and standing, expressed in Calories per minute, are compared with those from other studies reported recently, including the studies cited above.

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[3] "Highly significant" denotes that the data were tested at the 1-percent probability level; "significant" denotes the 5-percent level.

TABLE 1.—*Energy expenditures of six women when lying, sitting, and standing*

Subject	Age	Height	Weight[1]	Surface area	Lying[2]		Sitting[2]		Standing[2]	
	Years	*Cm.*	*Kg.*	*m²*	*Cal./hr.*	*Cal./hr./m²*	*Cal./hr*	*Cal./hr./m²*	*Cal./hr.*	*Cal./hr./m²*
44	40	163.5	63.21	1.67	59.5	35.6	70.5	42.2	71.3	42.7
45	40	163.0	70.23	1.74	59.1	34.0	61.5	35.4	64.8	37.2
20	30	163.0	60.40	1.63	56.7	34.8	60.1	36.9	66.9	41.1
43	40	161.9	63.79	1.66	59.3	35.7	68.1	41.0	67.5	40.7
54	46	160.9	61.23	1.63	56.5	34.7	62.7	38.5	67.8	41.8
31	35	160.7	63.60	1.65	49.5	30.0	52.7	32.0	57.3	34.8
Mean	38	162.2	63.74	1.66	56.8[a]	34.1[a]	62.6[b]	37.6[b]	65.9[c]	39.7[c]
Standard deviation					7.2	4.3	8.1	4.9	6.6	4.0

[1] Weight at time of test. [2] Values are means of 22 trials for each subject or a total of 132 measurements.

NOTE.—For values with the same units of measurement differences between means marked with different superscripts are significant at the 1-percent level of probability.

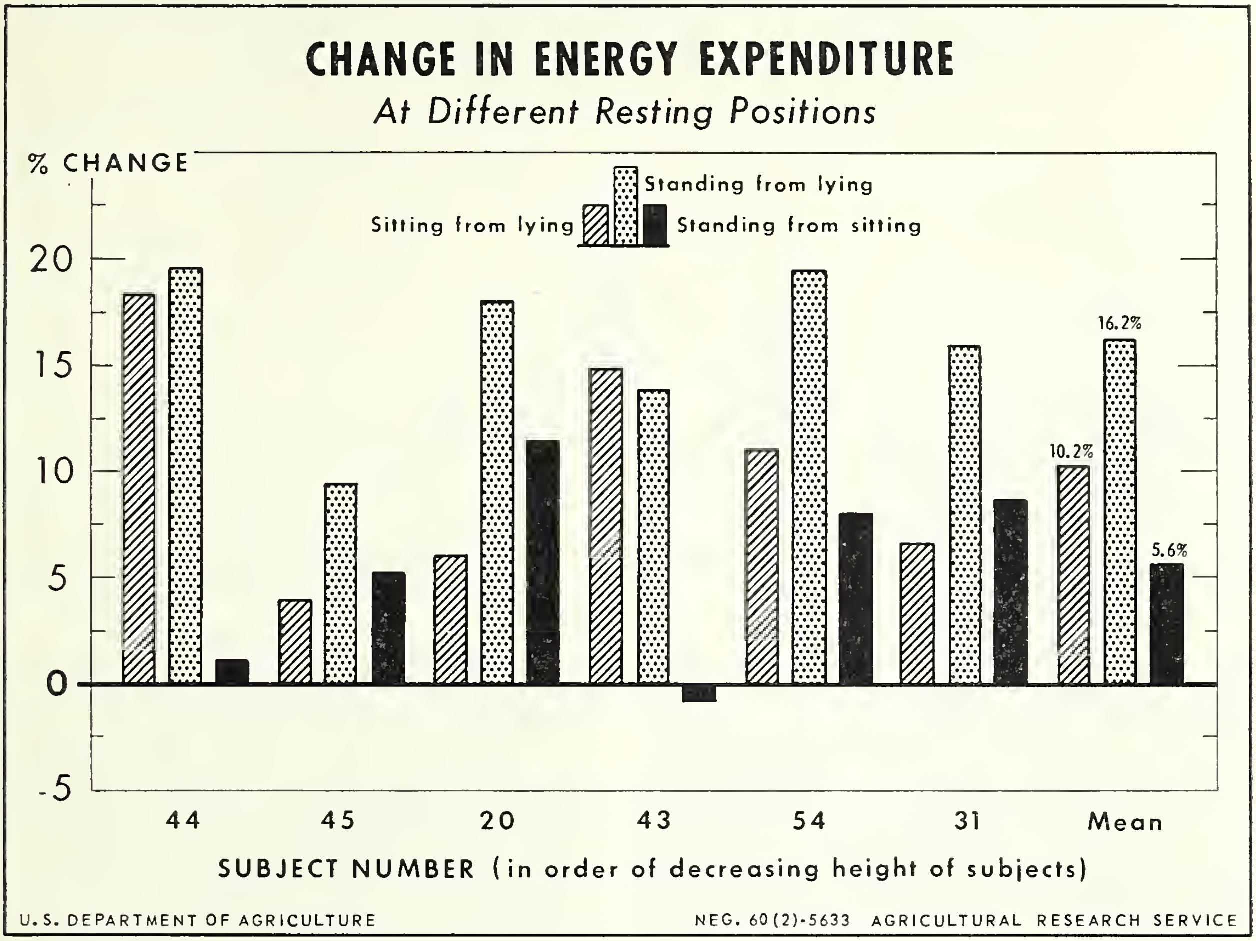

FIGURE 1.—Comparison, in percent, of the energy expenditures of six women for lying, sitting, and standing.

Table 2 also includes mean values for more than 6,000 determinations obtained during preactivity and postactivity periods of sitting and standing that were part of the procedures for other phases of the study. The latter values are comparable with those from the specific study, since differences in procedures were only minor. In the preactivity procedure, the subject rose from a lying position, walked a short distance to the testing area, and rested in a sitting or standing position while the apparatus was being placed in position. The values for the postactivity sitting or standing were taken approximately 1 minute after the activity ended; the 1-minute interval was the time required to remove and replace sample collection bags and to read meters and record readings.

The effect of preceding activity on energy expenditures during sitting or standing is indicated in the higher values for the postactivity than for the preactivity periods. These values may be more representative of actual energy expenditure of homemakers than those from the specific study, since during a day, sitting and standing are likely to be preceded by an activity requiring more energy than lying.

Considerable variation among subjects was observed in all tests. The average for each subject differed widely from the average for the group, whether the subjects were lying, sitting, or standing (fig. 2), confirming the work of Edholm and coworkers (*22*). Standard deviations in Calories per hour per square meter for lying, sitting, and standing (4.3, 4.9, and 4.0, respectively, table 1) are of the same order as those reported by Booyens and McCance (*8*).

No consistent relationship was found between an individual's deviation from the group in energy expenditure and her deviation from the group in basal heat production. Subject 45, for example, who had the highest metabolic rate, had next to the lowest energy expenditure when standing (fig. 2). A possible explanation might be the restrictions on the sample which eliminated extremes in basal rates. The variations were not consistently related to age, height, or the weight-height ratio of the subjects.

The energy expenditures of each of the subjects varied with the time of day the test was made (table 3). The specific dynamic action of food was probably responsible, since morning tests usually started 2 or 3 hours after breakfast, whereas after-

TABLE 2.—*Findings from various studies on energy expenditures of women for lying, sitting, and standing*

Reference	Subjects	Tests	Energy expenditure		
			Lying	Sitting	Standing
From literature:	*Number*	*Number*	*Cal./min.*	*Cal./min.*	*Cal./min.*
Booyens and McCance (*8*)	14	28	0.97	1.13	1.27
Bratton (*10*)	20	116		.99	
	12	82		.95	
Brown [1] [2] (*12*)			1.03–1.10	1.10–1.43	1.22–1.49
Sherman [1] (*51*)			[3] 1.10	[3] 1.43	[3] 1.50
Spector [1] (*54*)	57			[3] 1.09	
	16				[3] 1.11
This study:					
Specific activity tests	6	132	.95	1.04	1.10
Preactivity and postactivity periods: [4]					
Preactivity	14	915		1.06	
Postactivity	14	910		1.13	
Preactivity	14	1921			1.08
Postactivity	14	2328			1.18

[1] Compiler.

[2] Data for college students.

[3] On the basis of 60-kg. weight.

[4] Data based on measurements made in preactivity and postactivity periods for all tests (see p. 7).

noon tests started within an hour after lunch. Fatigue did not seem to be a factor; of the 18 highest readings, only 2 were obtained late in the afternoon (subjects 45 and 43). The findings agreed with those of Durnin and Weir (*21*), who reported that the variations with the time of day became significant between the 5- and 10-percent levels. This, they concluded, was the result of the "increased metabolic rate in the postprandial measurements, presumably due to the specific dynamic action of the previous meal."

Walking

Energy expenditures were determined for six women walking under the following conditions: (1) At four rates of stepping; (2) with 90-degree and 180-degree turns; and (3) while carrying an 18-pound load and while pulling the load on a cart.

Walking at four speeds.—Various investigators have measured energy expended in walking on the level at different speeds. Smith and Doolittle (*52*) found that the "energy expenditure (per gram calorie per horizontal-kilogram-meter) of women during horizontal walking is of the same degree as that of men when walking at moderate speeds." The women's expenditures were greater at abnormally slow speeds than at moderate speeds. Passmore and Durnin (*46*) compiled a composite graph of the results of work in laboratories in England, Austria, the United States, Germany, and Italy, which shows remarkable agree-

TABLE 3.—*Ranges of energy expenditures of six women for lying, sitting, and standing, by time of testing*

Subject	Position	Lowest reading		Highest reading	
		Calories per hour	*Time of day*	*Calories per hour*	*Time of day*
44	Lying	39.7	1:15 p.m.[1]	68.3	1:00 p.m.[1]
	Sitting	58.2	10:30 a.m	81.2	1:00 p.m.[1]
	Standing	59.4	10:00 a.m	82.8	1:00 p.m.[1]
45	Lying	38.0	11:10 a.m	84.9	8:30 a.m.
	Sitting	31.5	11:10 a.m	91.7	1:40 p.m.[1]
	Standing	45.4	11:10 a.m	84.1	3:45 p.m.
20	Lying	34.9	9:30 a.m	67.1	10:00 a.m.
	Sitting	47.0	1:00 p.m	70.3	12:00 Noon
	Standing	57.2	10:45 a.m	77.5	1:05 p.m.[1]
43	Lying	49.7	12:00 Noon	65.4	3:00 p.m.
	Sitting	53.2	11:05 a.m	77.9	10:00 a.m.
	Standing	57.2	10:50 a.m	80.3	1:30 p.m.[1]
54	Lying	31.9	11:00 a.m	76.8	2:30 p.m.
	Sitting	46.4	10:40 a.m	82.1	1:20 p.m.[1]
	Standing	54.2	10:40 a.m	86.2	1:20 p.m.[1]
31	Lying	30.7	1:20 p.m.[1]	59.1	9:30 a.m.
	Sitting	40.7	8:45 a.m	66.6	9:50 a.m.
	Standing	42.9	9:30 a.m	76.7	2:00 p.m.

[1] Immediately after lunch.

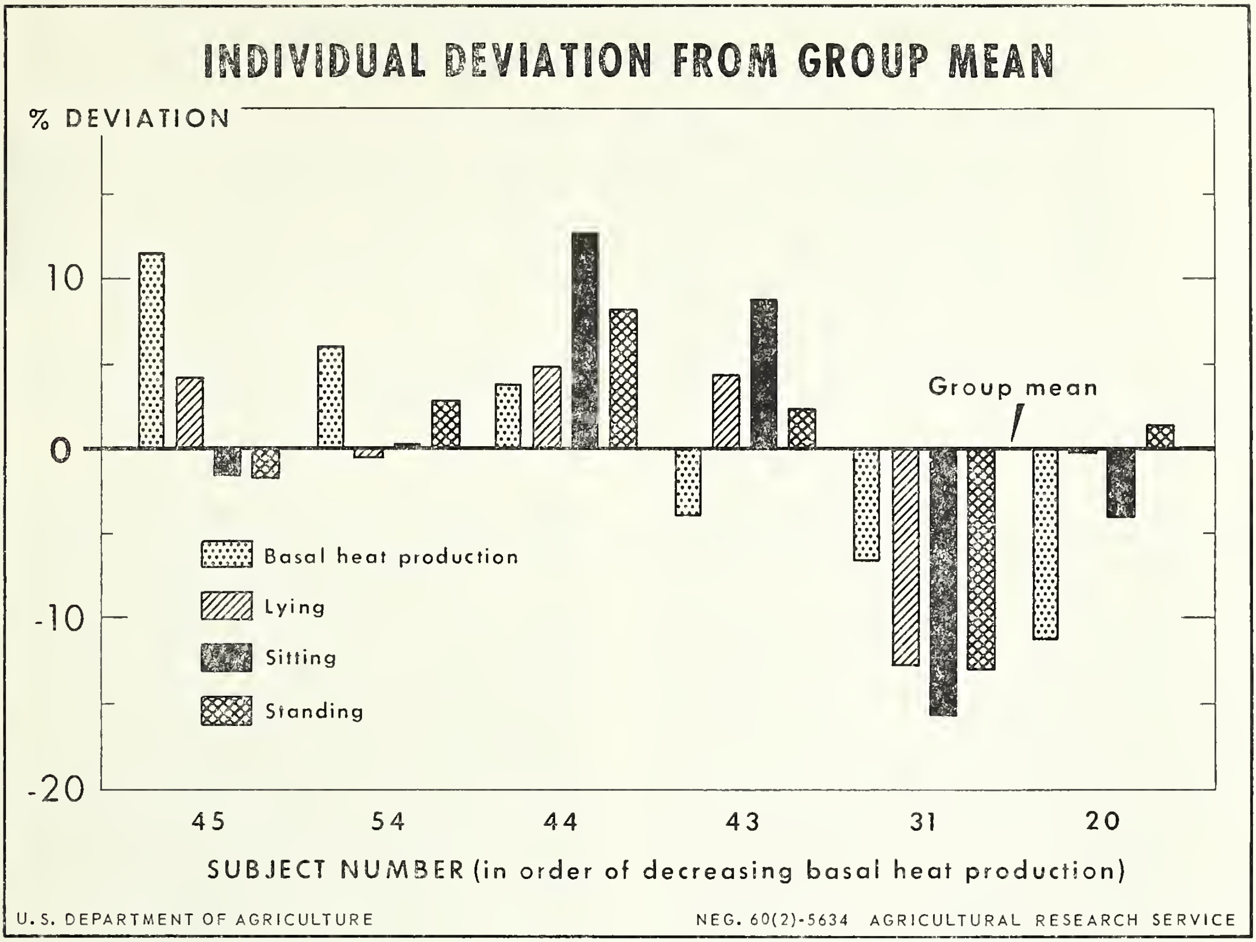

FIGURE 2.—Percentage deviation of six women from the group mean for basal heat production, and for energy expenditures when lying, sitting, and standing.

ment for energy expenditures for walking at various speeds. Only a minor degree of scatter was found at any given rate. Booyens and McCance (*8*) found less close agreement between subjects, though the order of values was the same.

In the current study of energy expended while walking, the women were the same as those participating in the preceding tests. They walked at their own natural gaits, which averaged 119 steps per minute (range, 107 to 131), and at the rates of 96, 108, and 120 steps per minute, controlled by a metronome—2.9, 2.2, 2.6, and 2.9 miles per hour, respectively.

In each of the tests the subjects walked down a corridor covered with inlaid battleship linoleum, made a wide turn, and returned to complete a measured course of 414 feet.

A test sequence was composed of a preactivity period of standing quietly for 3 minutes, three activity periods of walking at various stepping rates for approximately 1½ minutes each, and a postactivity period of standing quietly for 3 minutes. Between activity periods, the subjects rested sitting down for at least 2 minutes. The order of performance of the measured stepping rates was selected at random.

Five work sequences were performed by each woman in a day. A total of 192 energy-expenditure measurements were made for the "own-gait" rate and 180 for each of the controlled rates.

Mean energy expenditures for walking at the four rates were 161.6, 140.7, 146.3, and 158.9 Calories per hour, respectively (table 4), or 2.6, 2.3, 2.4, and 2.6 Calories per minute. On a weight basis, the subjects expended 2.53, 2.19, 2.28, and 2.48 Calories per hour per kilogram at the four rates.

Differences in energy expenditure per unit of time for walking at the three controlled rates were highly significant. Mean expenditures at 108 and 120 steps per minute were 3.9 and 12.9 percent larger, respectively, than for walking at 96 steps per minute. For the group, energy expenditures for their own stepping rates, which ranged from 107 to 131 steps per minute, did not differ significantly from that at the 120 steps-per-minute rate.

Further analysis of the data shows that these energy expenditures (Cal./min.) were in essentially linear relationship to the speed of walking (km./hr.).

TABLE 4.—*Energy expenditures of six women for walking at different rates of stepping*

Subject[1]	Subject's own stepping rate			96 steps per minute[2]			108 steps per minute[2]			120 steps per minute[2]		
	Cal./hr.	*Cal./hr./kg.*	*Cal./step*	*Cal./hr.*	*Cal./hr./kg.*	*Cal./step*	*Cal./hr.*	*Cal./hr./kg.*	*Cal./step*	*Cal./hr.*	*Cal./hr./kg.*	*Cal./step*
44	[3] 143.0	[3] 2.14	[2] 0.0208	140.2	2.09	0.0243	146.9	2.19	0.0228	153.5	2.28	0.0220
45	[4] 170.9	[4] 2.49	[4] .0236	157.6	2.24	.0270	156.9	2.23	.0246	165.9	2.36	.0236
20	[3] 162.4	[3] 2.68	[3] .0248	138.1	2.28	.0236	146.7	2.42	.0223	160.3	2.65	.0223
43	[3] 186.0	[3] 2.91	[3] .0238	148.4	2.33	.0258	158.0	2.48	.0246	175.1	2.76	.0244
54	[3] 168.6	[3] 2.76	[3] .0212	131.8	2.17	.0222	133.6	2.19	.0202	153.5	2.52	.0209
31	[4] 138.6	[4] 2.18	[4] .0217	128.4	2.05	.0223	135.8	2.17	.0213	144.9	2.32	.0205
Mean	161.6[a]	2.53[a]	.0226[a]	140.7[c]	2.19[c]	.0242[c]	146.3[b]	2.28[b]	.0226[b]	158.9[a]	2.48[a]	.0223[a]

[1] Subjects' mean weight at time of testing was 64.20 kg.

[2] Values are means of 30 trials for each subject, or a total of 180 measurements.

[3] Mean of 27 trials.

[4] Mean of 42 trials.

NOTE.—For expenditures with the same units of measurement, differences between means marked with different superscripts are significant at the 1-percent level of probability.

The correlation was highly significant (r=0.58). This finding is in agreement with results indicated in Passmore's graph, referred to above, though the slope of the line is slightly different.

The values found in this study are lower than those reported by several other investigators. Douglas and Haldane (*18*) noted an energy expenditure of 3.4 Calories per minute for one subject, a man, walking at a speed of 2 miles per hour. A value of 2.9 Calories per minute was reported by Passmore and Durnin (*46*) for walking at a rate of 2 miles per hour. Spector (*54*) reported a mean expenditure of 2.84 Calories per minute for nine women walking at the rate of 2.2 miles per hour. Brown (*12*) gave a value of 2.60 to 2.80 Calories per hour per kilogram for walking at a speed of 2.5 miles per hour.

Expressed in terms of horizontal distance covered, energy expenditures increased at the slower stepping rates. Mean expenditures for the subjects' natural rate of 119 steps per minute and for the controlled rates of 96, 108, and 120 steps per minute were 55.6, 62.6, 56.5, and 54.1 Calories per mile, respectively (table 5). The value for the 96-step rate is significantly different from that for each of the higher rates. Calculated on the basis of body weight, mean expenditures were 0.53 gram calories per kilogram-meter at 120 steps per minute, and 0.62 and 0.57 gram calories per kilogram-meter at 96 and 108 steps per minute.

Similar results have been reported by Smith and Doolittle (*52*) and by Benedict and Parmenter (*5*). The latter found that, for their subjects, the "optimum" of the rates of speed studied was 65 meters per minute (2.4 miles per hour). They reported that increases in heat production for walking, compared with standing, were greater at speeds of 34 meters than at 65 meters per minute. Their work and that reported here thus indicate that sauntering is uneconomical in energy expenditure in relation to the distance covered.

The increase in energy expenditure per unit of distance at the lower speeds can no doubt be explained by the fact that the women took more steps to walk a given distance at a slow rate of stepping than at a faster rate (table 6). The relationship between the number of steps taken and the speed in kilometers per hour showed a highly significant negative correlation (r=0.73). Mahadeva and coworkers (*35*) have reported that the "metabolic cost of moving or lifting the body * * * can be predicted with reasonable accuracy with weight alone." Thus, as the number of lifts (steps) increased, the energy expenditure per unit of distance covered increased.

As the pace approached that at which the women were accustomed to walk, their ease in keeping step with the metronome increased, and they expended the least energy per unit of distance covered. Two of the women could not keep in step with the metronome; they showed the widest variation in the number of steps taken. The other four showed a good sense of rhythm, even during the "own-gait" tests without the metronome; their variation was only one or two steps. The strides and ways of walking of all the women were individualistic. No attempt was made to alter them.

Energy expenditure for walking at the different rates was not significantly correlated with weight (r=0.26). The relatively large individual differences in ways of walking and the limited range in weight may have occluded any significant relation between weight and energy expenditures. These findings differ from those of Erickson (*23*), Mahadeva and coworkers (*35*), Miller and Blyth (*42*), Seltzer (*50*), and Brockett and coworkers (*11*), who found a high correlation between body weight and energy cost of walking at various speeds. Delbue and coworkers (*14*) did not obtain this high correlation.

The relationship of certain leg-length measurements to energy expenditure for walking was also studied. The correlation of crotch height and energy expenditure for walking was not significant (r=0.32). The woman with the shortest legs took the most steps to cover the distance at the lowest stepping rate. However, energy expenditures varied for the individual subjects and between subjects, whereas anthropometric differences between the women were small.

Walking with 90- and 180-degree turns.—For the study of energy requirements for walking with 90-

Table 5.—*Energy expenditures per unit of distance covered, for six women when walking at different rates of stepping*

Subject	Steps per minute [1]	Energy expenditure [2]	
	Number	*Calories per mile*	*Calories per kilometer*
44	Controlled rate:		
	96	59.8	37.1
	108	55.9	34.8
	120	53.9	33.5
	Subject's own rate:		
	115	[3] 51.9	[3] 32.3
45	Controlled rate:		
	96	65.9	41.0
	108	59.2	36.8
	120	55.2	34.3
	Subject's own rate:		
	121	[4] 53.9	[4] 33.5
20	Controlled rate:		
	96	65.1	40.4
	108	57.8	35.9
	120	56.6	35.2
	Subject's own rate:		
	110	[3] 61.9	[3] 38.4
43	Controlled rate:		
	96	71.8	44.6
	108	64.5	40.1
	120	61.2	38.1
	Subject's own rate:		
	130	[3] 62.5	[3] 38.8
54	Controlled rate:		
	96	55.2	34.3
	108	47.9	29.7
	120	45.9	28.5
	Subject's own rate:		
	131	[3] 51.3	[3] 31.9
31	Controlled rate:		
	96	57.8	35.9
	108	53.9	33.5
	120	51.9	32.3
	Subject's own rate:		
	107	[4] 53.9	[4] 33.5
Weighted means.	Controlled rate:		
	96	62.6[a]	38.9[a]
	108	56.5[b]	35.1[b]
	120	54.1[b]	33.6[b]
	Subject's own rate:		
	119	[5] 55.6[b]	[5] 34.5[b]

[1] At 96 steps per minute the women walked at the rate of 2.2 miles per hour; at 108 steps per minute, 2.6 miles per hour; at 120 steps per minute, 2.9 miles per hour. Mean of subjects' own stepping rates, at 119 steps per minute, the women walked at 2.9 miles per hour.

[2] Unless otherwise specified, values are means of 30 trials for each subject or a total of 180 measurements.

[3] Mean of 27 trials.

[4] Mean of 42 trials.

[5] Mean of 192 trials.

Note.—For expenditures with the same units of measurement, differences between means marked with different superscripts are significant at the 1-percent level of probability.

and 180-degree turns the subjects were the same six women who participated in the lying, sitting, and standing, and the rates-of-stepping tests.

They also walked at a rate of 96 steps per minute for a distance of 414 feet, but made a turn at each 10-foot interval. The course for walking with 90-degree turns was a 10-foot square; a 10-foot shuttle course was used for the 180-degree turns.

Five work sequences were performed by each woman in a day. Each sequence included six periods of alternating standing at rest and walking with either 90- or 180-degree turns for approximately 3 minutes. The walk-turn activity to be tested was selected at random. For each of the activities, 180 measurements were made, 30 for each of the subjects.

Mean energy expenditures for walking with 90- and 180-degree turns were, respectively, 162.8 and 166.6 Calories per hour (2.713 and 2.776 Calories per minute) and 0.0282 and 0.0289 Calories per step (table 7). Although walking with 90-degree turns took less energy, the difference was not significant. Energy expenditure for walking with the 90- and 180-degree turns was 16 and 18 percent larger, respectively, than that for walking in a straight line at the same controlled rate of 96 steps per minute. These differences were highly significant.

Walking with a load.—The energy cost of load carrying has been studied by a number of investigators. Bedale (*3*), who determined the energy expenditure of subjects carrying loads while walking at the rate of 4.5 kilometers per hour, found that with the use of a yoke across the shoulders, the energy expenditure was minimal; when the load was carried by holding it on the hip, the expenditure was maximal. Intermediate values were obtained for carrying trays in either hand in front of the body, with and without a strap over the shoulder, and for carrying bundles on the head or over the shoulder.

Passmore and Durnin (*46*) reported that results obtained by Brezina and Kolmer, who measured the energy expenditure of a young man carrying a knapsack, and those reported by Cathcart, Richardson, and Campbell, and by Atzler and Herbst were similar. These studies indicated "that at slow speeds energy expenditure even with a 43-kg. load is not high, but that when the speed rises over 4 km./hr. energy expenditure increases rapidly." Glascow and Müller (*24*), Lignori (*34*), and Dressel,

Table 6.—*Steps taken by six women to cover a distance of 414 feet when walking at different stepping rates*

Subject	Steps at subject's own gait	Steps at 96 steps per minute [1]	Steps at 108 steps per minute [1]	Steps at 120 steps per minute [1]
	Number	*Number*	*Number*	*Number*
44	[2] 195.3	193.3	192.1	191.3
45	[3] 178.0	192.0	188.9	184.2
20	[2] 195.7	220.1	204.1	198.5
43	[2] 204.4	218.0	217.4	195.9
54	[2] 188.8	196.8	187.8	173.4
31	[3] 196.2	203.1	196.9	198.1
Mean	[4] 193.1[a]	203.9[b]	197.9[c]	190.2[a]

[1] Values are means of 30 trials for each subject or a total of 180 measurements.

[2] Mean of 27 trials.

[3] Mean of 42 trials.

[4] Mean of 192 trials.

Note.—Differences between means marked with different superscripts are significant at the 1-percent level of probability.

Table 7.—*Energy expenditures of six women for walking in a straight line and with 90-degree and 180-degree turns at a rate of 96 steps per minute*

Subject	Walking in a straight line [1]	Walking with 90-degree turns [1]			Walking with 180-degree turns [1]		
	Cal./hr.	*Cal./hr.*	*Cal./min.*	*Cal./step*	*Cal./hr.*	*Cal./min.*	*Cal./step*
44	140.2	153.8	2.563	0.0267	153.2	2.554	0.0266
45	157.6	169.5	2.825	.0294	191.0	3.184	.0331
20	138.1	179.3	2.987	.0311	174.6	2.911	.0302
43	148.4	175.4	2.924	.0305	167.2	2.787	.0291
54	131.8	152.5	2.539	.0265	159.6	2.661	.0277
31	128.4	146.3	2.438	.0253	153.7	2.562	.0267
Mean	140.7 [a]	162.8 [b]	2.713 [c]	.0282 [d]	166.6 [b]	2.776 [c]	.0289 [d]

[1] Values are means of 30 trials for each subject or a total of 180 measurements.

Note.—Differences between means for walking with either turn and walking in a straight line are significant at the 1-percent level of probability. Differences between means marked with the same letter superscripts for walking with 90-degree and 180-degree turns are not significant.

Karrasch, and Spitzer (*19*) have also reported studies of men walking while carrying or pulling heavy loads.

The energy expenditure of the six women for walking while carrying a load was compared with that for walking while pulling the same load on a cart.

Participants in this phase of the study were subjects 23, 29, 31, 32, 43, and 54 (table 15). Means determined at the beginning of the study for height, weight, age, and basal metabolic rate were 63.5 inches, 135.9 pounds, 37 years, and −8 percent, respectively.

The load was a flexible plastic laundry basket filled with clothes to make a total weight of 18 pounds. The basket, with a handle at each end, measured 25 by 27 inches at the top and 10¾ inches in depth.

For the walk-carry activity, the women carried the basket down a corridor and back, a total distance of 414 feet, at a metronome-controlled rate of 120 steps per minute. Covering this distance took about 1½ minutes. The total number of steps taken by each individual, the total time to complete the prescribed distance, and the method of carrying the basket were not regulated. However, each subject established her own method of carrying the basket and continued that method throughout all the tests.

For the walk-pull tests the cart used was made of metal tubing and fitted with small caster wheels. Its dimensions were 19 by 10½ inches and it stood 20¼ inches from the floor. The loaded basket was placed on top of the cart, which was pulled with one hand. The cart offered little resistance to pulling. The women traversed the same course and walked at the same stepping rate as when carrying the load.

Each work sequence included the following:

1. A preactivity period of standing quietly for 3 minutes.
2. A warmup period of 20 seconds in which a walk-carry or a walk-pull activity was performed. (No sample was collected during this period.)
3. An activity period of approximately 1½ minutes during which the same activity as in the warmup period was performed.
4. Two repetitions of operations 2 and 3, with measured rest periods between.
5. A postactivity period of standing quietly for 3 minutes.

The order of performance of the carry or pull activity was selected at random. Six work sequences were performed each day and 36 replications per woman per activity were completed—a total of 432 tests.

The mean energy expenditures for the walk-carry and walk-pull activities were, respectively, 287.4 and 269.2 Calories per hour (4.791 and 4.488 Calories per minute), and 4.672 and 4.376 Calories per hour per kilogram of body weight (table 8). On these bases, differences between expenditures for the two activities were not significant, but were significantly different from those for walking at the same rate without a load. The increases were 81 and 69 percent, respectively. In Calories per step the expenditures were 0.0406 and 0.0373; the differences were significant.

Correlation of the walk-carry energy expenditures with the subjects' leg lengths showed a negative relationship (r=0.65). The individuals with the shorter legs expended the most energy probably because of the increased number of body lifts (steps) required to complete the distance.

Trunk- and Knee-Bending Activity

Knowles (*30*), investigating the energy expenditures of four women for bending while ironing in a standing position, found a significant difference in expenditures between the 12-degree and 34-degree bends. The women expended from 14 to 32 percent more energy with the 34-degree bend. Bratton (*9*) found that women consumed more oxygen when reaching down to 3 inches above the floor by means of a deep knee-bend than by any of the other bends studied.

TABLE 8.—*Energy expenditures of six women when walking at a rate of 120 steps per minute while carrying an 18-pound load and while pulling the load on a cart*

Subject [1]	Walk-carry [2]				Walk-pull [2]			
	Cal./hr.	*Cal./min.*	*Cal./step*	*Cal./hr./kg.*	*Cal./hr.*	*Cal./min.*	*Cal./step*	*Cal./hr./kg.*
23	266.8	4.447	0.0369	4.539	268.0	4.467	0.0363	4.559
29	269.5	4.492	.0378	4.657	236.6	3.943	.0330	4.089
31	256.7	4.279	.0357	4.108	238.0	3.968	.0329	3.809
32	366.1	6.102	.0509	5.773	316.3	5.271	.0441	4.987
43	291.3	4.855	.0403	4.454	290.6	4.843	.0401	4.443
54	274.1	4.569	.0420	4.504	266.0	4.433	.0368	4.371
Mean	287.4	4.791	.0406 [a]	4.672	269.2	4.488	.0372 [b]	4.376

[1] Mean weight of subjects at time of tests, 61.47 kg.

[2] Values are means of 36 trials for each subject, or a total of 216 measurements.

NOTE.—Within a unit of measurement, means for the walk-carry and the walk-pull activities are not significantly different except on a per-step basis. Differences between means with superscripts are significant at the 5-percent level probability.

In the present study of energy expenditure for trunk- and knee-bending the subjects were the same six women used in the lying, sitting, standing study.

The test procedure consisted of removing a 5-pound load from a counter 36 inches high and placing it on a shelf 12 inches above the floor. The load was a 2-pound pan with contents weighing 3 pounds. The pan was 8 inches in diameter and 4 inches deep, with two handles, one on each side.

Details of the procedure were as follows:

1. Stand with hands at sides.
2. Grasp the pan with both hands.
3. Remove the pan from the work surface and place it on the shelf by trunk- or knee-bending.
4. Return to an upright position with hands at sides.
5. With trunk- or knee-bend as in step 3, bend and grasp the pan with both hands, returning it from the low shelf to the work surface.
6. Return hands to sides, and at the same time click the mechanical counter as the hands are lowered.

Each subject performed the procedure at her own established rhythm, which she maintained throughout each test period.

Each procedure took about 9 seconds; 10 procedures were completed in each 1½-minute-test period. The subjects sat quietly for 1 minute between test periods. This interval allowed time for the technician to change sample bags and record the data.

A work sequence included two periods each of trunk-bending and knee-bending activities, with a preactivity and a postactivity period of standing quietly for 3 minutes. The order of the activities was randomized. Ten work sequences were completed in a day. The tests included 20 periods of each activity for each subjects—a total of 240 measurements.

An expired-air sample was collected for a period of 1½ minutes; activity time was recorded to the end of the last procedure.

The mean energy expenditures of the six subjects for the trunk-bending and the knee-bending activities were, respectively, 173.2 and 224.3 Calories per hour (2.887 and 3.738 Calories per minute), as shown in table 9. These findings are comparable to those of Bratton (*9*), who reported expenditures of 2.88 and 4.12 Calories per minute for a trunk- and deep knee-bend, respectively. Considerable variation between subjects was observed. Subject 31 showed the most variation for knee-bending and the least for trunk-bending; subject 43 showed the most variation for trunk-bending and subject 44 showed the least variation for knee-bending.

Compared with a mean energy expenditure of 65.9 Calories per hour for standing at rest, expenditures for trunk- and knee-bending showed highly significant increases of 163 and 240 percent, respectively. These increases over standing are larger than the 131 and 224 percent increases over standing for trunk- and knee-bending, respectively, reported by Bratton (*9*), who measured the oxygen consumed.

On the basis of expenditures per procedure, the means were 0.430 and 0.609 Calories for the trunk- and knee-bending activities, respectively. These results were affected by the individual rhythms and rates of work and showed a greater and highly significant difference (43 percent) between expenditures for the two activities than did results on a time-unit basis.

Approximately 30 percent more energy on the basis of Calories per hour, and 40 percent more on the basis of Calories per procedure, were required for a knee-bend. This is what might be expected if only the amount of body weight lifted were considered. For trunk-bending, this weight is relatively small (from the waist up), but is large (almost the entire body) for knee-bending.

Factorial and Continuous Measurements

Homemaking necessitates different types of activities. Each activity consists of many components which may be performed at any time during the activity and any one of which may be affected by

TABLE 9.—*Energy expenditures of six women for performing trunk-bending and knee-bending activities;*[1] *means and standard deviations*

Subject[2]	Trunk-bend[3]	Knee-bend[3]	Trunk-bend[3]	Knee-bend[3]	Trunk-bend[3]	Knee-bend[3]	Increase[4]	Trunk-bend[3]	Knee-bend[3]	Increase[4]
	Cal./hr.	*Cal./hr.*	*Cal./min.*	*Cal./min.*	*Cal./hr./kg.*	*Cal./hr./kg.*	*Percent*	*Cal. per procedure*	*Cal. per procedure*	*Percent*
20	179.2±11.0	219.6±19.8	2.986±.18	3.659±.33	2.906±.17	3.560±.31	22.54	0.449±.03	0.527±.05	17.37
31	137.7± 8.3	188.6±24.1	2.294±.14	3.142±.40	2.206±.13	3.023±.37	36.96	.355±.02	.420±.05	18.31
43	173.1±15.1	265.2±20.6	2.885±.25	4.420±.34	2.691±.24	4.124±.32	53.21	.432±.04	.861±.07	99.31
44	188.1±12.5	220.4±11.1	3.135±.21	3.673±.18	2.889±.19	3.384±.17	17.17	.493±.03	.607±.03	23.12
45	180.0±10.8	224.4±15.9	3.001±.18	3.741±.26	2.529±.17	3.153±.25	24.67	.489±.03	.616±.04	25.97
54	181.2±12.4	227.5±22.1	3.020±.21	3.790±.37	2.953±.19	3.701±.34	25.55	.362±.02	.625±.06	72.65
Mean	173.2±11.6	224.3±19.1	2.887±.19	3.738±.32	2.696±.18	3.491±.30	29.50	.430±.03	.609±.05	42.79

[1] One procedure was as follows: Starting from (1) a rest position with hands at sides, (2) the subject grasped the pan with both hands; (3) removed a 5-pound load from a counter 36 inches high, and bending, placed it on a shelf 12 inches from the floor; (4) returned to upright position with hands at sides; (5) bent to retrieve pan, returning it to the counter; (6) and returned hands to sides.

[2] Mean weight of subjects at time of tests, 64.34 kg.

[3] Values are means of 20 trials for each subject, or a total of 120 measurements.

[4] Increase in energy expenditure for knee-bending over that for trunk-bending.

NOTE.—Differences between means for each set of knee- and trunk-bending activities are significant at the 1-percent level of probability.

another just before it. For example, paring vegetables may be immediately preceded by bending to procure a utensil or to put a load in an oven, or by a period of walking or sitting. Any of these activities, if an oxygen debt is involved, would have an effect on the energy measurement during the time of the paring activity, even though it is not a part of that activity.

The investigation reported here was made primarily to determine under what conditions factorial measurements might give the same results as those obtained by continuous measurements. Rankin and coworkers (*49*), using the factorial method, supported the validity of the comparison of the two methods. The effect of oxygen debt was also investigated here.

Two components were studied—trunk-bending and walking up and down stairs. They were chosen because they could easily be performed consecutively without intervening motion or time and are quite different in energy requirements.

Five women were used—subjects 20, 31, 43, 44, and 54 (table 15). At the beginning of this study, means for their height, weight, age, and basal metabolic rate were 63.9 inches, 136.9 pounds, 38 years, and −8 percent, respectively.

Motions were standardized for each activity. For the bending activity the subjects, holding a light wooden bar in both hands, stooped from the waist and placed the bar on the bottom step of a flight of wooden stairs; then removed it. The motions were performed to the count of a metronome, set at 88 beats per minute, as follows: Counts 1 and 2, bend and place the bar; 3 and 4, return to standing position; 5 and 6, bend and pick up the bar; 7 and 8, return.

In the stair-climbing activity three steps were climbed during the first three counts; on the count of 4 both feet were on the third step. The procedure was reversed for counts 5 to 8, the subjects walking backwards down the three steps.

For a combination of trunk-bending and stair-climbing activities, the eight counts of each activity were performed alternately.

During each work sequence, a trunk-bending activity, a stair-climbing activity, and a combination of the two were performed, each for a count of 96, or a period of approximately 1 minute and 6 seconds. Before and after each set of the three activities, energy-expenditure measurements were taken while the subjects stood at rest for 3 minutes. The order of performance of the activities was randomized, so that each was performed several times first, second, and third in the sequence. For each woman, 135 tests were performed, or 225 for each schedule and activity—a total of 675 tests.

To ascertain whether the occurrence of an oxygen debt would distort an additive relationship between the components, the work sequences were performed three ways, as shown by the schedules in table 10. In schedules A and B the length of the warmup period prior to the activity measurement was varied 11 and 30 seconds, respectively. In schedule C the warmup period was omitted and the collection period was extended to 4 minutes to include 2 minutes and 54 seconds of standing quietly at the end of the actual activity period. Hence, recovery from any oxygen debt due to the activity was in the measurement.

Mean energy expenditures in Calories per hour for the activities performed according to the three schedules are given in table 11. The values obtained by continuous measurement of the two activities were not significantly different from those obtained factorially.

Mean energy expenditures during the preactivity and postactivity periods of standing at rest are compared in table 12. For schedules A and B the differences were highly significant; increases in expenditures for the postactivity period over those for the preactivity period were 21.1 percent for schedule A and 23.7 percent for schedule B. Differences between the similar standing periods of schedule C were not significant.

Average energy expenditure of the five subjects when they performed the test activities first, second, and third in the sequence are shown in table 13 and figure 3. In schedules A and B, energy requirements for each activity were significantly greater when the activity was performed second or third than when it was performed first. In schedule B, with a longer warmup period preceding the activity, the percentage increases were less than in schedule A.

TABLE 10.—*Schedules for work sequence and collection of expired air for three activities*

Schedule	Preactivity collection period: Subjects standing at rest	Warmup period: No sample collection	Activity test period:		Postactivity collection period: Subjects standing at rest
			Activity [1]	Collection sample	
	Minutes	*Seconds*	*Minutes*	*Minutes*	*Minutes*
A	3.0	About 11 (1 unit of activity [2])	1.1	1.0	3.0
B	3.0	30 (of the activity)	1.1	1.1	3.0
C	3.0	None	1.1	[3] 4.0	3.0

[1] The three test activities, timed with a metronome set at 88 beats per minute and repeated throughout the duration of the tests as follows: (a) Trunk-bending to place bar on step and return to erect position (4 beats) and to pick up bar from step (4 beats); (b) walking up stairs (4 beats) and down (4 beats); and (c) alternating (a) and (b) for a total of 16 beats.

[2] Bending, 8 beats, and stair-walking, 8 beats, each approximately 5.45 seconds; or combined bending and stair-walking, 16 beats, approximately 10.9 seconds.

[3] Air sample collected during 1.1 minutes of activity and the following 2.9 minutes of standing at rest.

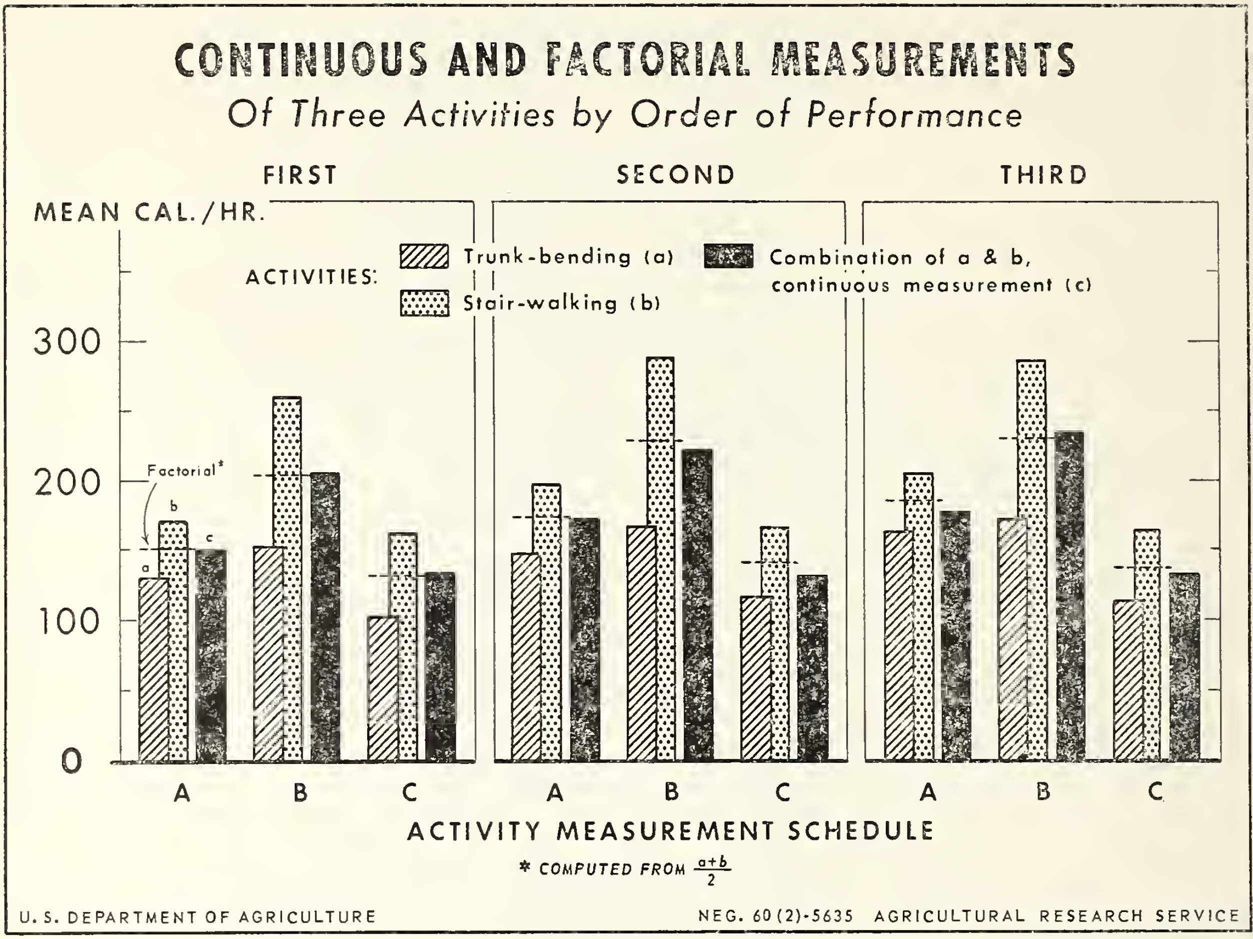

FIGURE 3.—Mean energy expenditures of five women for two activities measured continuously and factorially when performed first, second, and third in the test sequence of three activity schedules.

TABLE 11.—*Energy expenditures of five women for two activities as measured by continuous and factorial methods*

Schedule [1]	Trunk-bending [2]	Stair-walking [2]	Trunk-bending and stair-walking [2]	
			Continuous measurement	Computed factorially [3]
	(1)	(2)	(3)	(4)
	Cal./hr.	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*
A	147.8	191.5	166.8	169.6
B	164.9	278.8	220.6	221.9
C	111.0	164.9	132.8	137.8

[1] For descriptions of schedules see table 10.
[2] Values are means of 75 measurements.
[3] $\frac{\text{Col. } 1+\text{col. } 2}{2}$

NOTE.—Within a schedule differences between means determined by different methods are not significant.

In schedule C, in which there was no warmup and the measurements were made over a period to include recovery, the energy cost of bending was significantly greater when the activity was performed second and third in the sequence than when it was performed first. For stair-walking and the combination of activities, differences between values were not significant.

Results of this phase of the study indicate that when activities are being compared, the procedures of schedule A or schedule B may be used. When absolute values are to be determined, the procedure of schedule C should be used.

Anthropometric Measurements in Relation to Energy Expenditures

There has long been an interest in the relation of body size—which may be described by precise anthropometric measurements—to energy metabolism. In terms of the concept of lean-body mass this interest has been recently revived by Miller and Blyth (*41*). Dobeln (*15*) has approached this sub-

TABLE 12.—*Energy expenditures of five women while standing at rest during preactivity and postactivity periods*

Schedule [1]	Preactivity period [2]	Postactivity period [2]	Difference [3]
	Cal./hr.	*Cal./hr.*	*Percent*
A	65.1	78.8	21.1
B	62.9	77.8	23.7
C	63.9	64.0	0.2

[1] For descriptions of schedules, see table 10.

[2] Values are means of 225 measurements.

[3] Increase in energy expenditure for postactivity period over that for preactivity period.

NOTE.—For schedules A and B, differences between means for preactivity and postactivity are significant at the 5-percent level of probability. For schedule C, the difference is not significant.

ject in terms of the basal and maximal metabolism in man; Kleiber and coworkers (*29*) have attempted to codify the relation of metabolic rate to body size of rats and other small animals. A review of the development in this relation is given by Kleiber (*28*) and Nutrition Reviews (*1*).

Few studies have been reported on the relation of anthropometric measurements to energy expenditure for walking. Brockett and associates (*11*) have recently reported a highly significant relationship between leg length and energy expenditure for walking.

TABLE 13.—*Energy expenditures of five women for two activities when performed first, second, and third in the test sequence and as measured by the continuous and factorial method*

Schedule [1] and place of activity in performance sequence	Trunk-bending [2]	Stair-walking [2]	Trunk-bending and stair-walking [2]	
			Continuous measurement	Computed factorially [3]
	(1)	(2)	(3)	(4)
Schedule A:	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*
1st	130.9^{a}	171.4^{a}	150.6^{a}	151.2
2d	149.1^{b}	197.6^{b}	172.4^{b}	173.4
3d	164.4^{c}	205.5^{c}	177.5^{c}	185.0
Schedule B:				
1st	152.5^{a}	260.8^{a}	206.9^{a}	206.6
2d	168.8^{b}	289.0^{b}	221.5^{b}	228.9
3d	173.6^{b}	286.5^{b}	233.6^{c}	230.1
Schedule C:				
1st	102.4^{a}	162.9^{a}	133.6^{a}	132.7
2d	116.4^{b}	166.2^{a}	131.0^{a}	141.4
3d	114.2^{b}	165.2^{a}	133.8^{a}	139.6

[1] For descriptions of schedules see table 10.

[2] Values are means of 225 measurements.

[3] $\frac{\text{Col. 1+col. 2}}{2}$

NOTE.—Within a schedule and within an activity, differences between means marked with different superscripts are significant at the 5-percent level of probability.

Arm-length measurements of the women participating in other phases of the present study were correlated with energy expenditures for certain shelf-height reaches, but no significant relationship was found.

Anthropometric measurements of 10 of the women who participated in this project—subjects 11, 20, 23, 29, 31, 32, 43, 44, 45, and 54 (table 14)—were related to stature and to energy expenditures for specified activities. The measurements, given in table 14, were made by the method and with the type of calibrated instruments described by O'Brien (*44*).

The data indicate that variations among the subjects were small, as would be expected because of the

TABLE 14.—*Selected anthropometric measurements of 10 women 24 to 46 years of age*

Dimension	Mean measurement and standard deviation [1]	
	Centimeters	*Inches*
Height, standing (measured from floor):		
Top of head	160.6±2.16	63.2±0.85
Cervicale	136.0±2.39	53.6±0.94
Shoulder:		
Right	133.2±2.54	52.4±1.00
Left	133.1±2.26	52.4±0.89
Bust:		
Right	117.2±2.66	46.1±1.05
Left	117.3±2.83	46.2±1.11
Waist, to crest of ilium:		
Right	102.2±4.17	40.2±1.64
Left	102.3±3.97	40.3±1.56
Abdominal extension	91.3±2.78	34.9±1.09
Hip, to trochanter:		
Right	81.9±3.23	32.3±1.27
Left	82.0±3.09	32.3±1.21
Elbow, floor to olecranon:		
Right	101.4±1.96	39.9±0.77
Left	101.7±1.99	40.1±0.79
Wrist, floor to distal end of radius:		
Right	79.3±1.87	31.2±0.73
Left	79.1±1.89	31.1±0.74
Finger tip, floor to tip of longest finger:		
Right	61.3±1.74	24.1±0.68
Left	61.5±2.16	24.2±0.85
Knee, floor to top of tibia:		
Right	43.6±1.94	17.1±0.76
Left	43.4±1.78	17.1±0.70
Knee, floor to top of fibula:		
Right	40.1±1.60	15.8±0.63
Left	40.1±1.65	15.8±0.65
Crotch from floor	71.3±2.29	28.1±0.90
Height, sitting on table (measured from top of table):		
Cervicale	60.3±1.33	23.7±0.52
Thigh:		
Right	14.6±1.45	5.8±0.57
Left	14.1±1.58	5.6±0.62
Breadth:		
Shoulder	40.0±1.19	15.8±0.47
Bust	30.1±1.47	11.8±0.58
Waist	26.0±1.36	10.2±0.53
Hip	35.6±1.67	14.0±0.65
Arc:		
Bust	51.7±0.92	20.3±0.36
Waist	39.8±3.36	15.7±1.32
Hips	52.2±5.52	20.5±2.17

Table 14.—*Selected anthropometric measurements of 10 women 24 to 46 years of age*—Continued

Dimension	Mean measurement and standard deviation[1]	
	Centimeters	*Inches*
Girth:		
Bust	91.9±1.73	36.2±0.68
Waist (under the 12th rib)	72.9±3.49	28.7±1.37
Hip (trochanter level)	97.4±3.53	38.4±1.39
Abdominal extension	91.7±5.63	36.1±2.21
Thigh:		
Right	49.4±1.98	19.4±0.78
Left	48.2±1.75	19.0±0.69
Sitting spread	96.8±4.12	38.1±1.62
Arm length, apex of axilla to distal end of radius:		
Right	48.1±2.42	18.9±0.95
Left	48.5±2.68	19.1±1.05
Arm length, acromion to ulna:		
Right	57.2±2.11	22.5±0.83
Left	57.1±2.15	22.5±0.84
	Kg.	*Lbs.*
Weight[2]	61.0±2.49	134.3±5.49

[1] Means represent measurements of subjects 11, 20, 23, 29, 31, 32, 43, 44, 45, and 54 of table 15.

[2] No correction was made for the briefs and brassieres the women were wearing.

limitations on height and weight used in the selection of the sample. Greatest deviations were for abdominal extension, arc of the hip, height of waist, and sitting spread.

The correlation coefficient of 0.93 between shoulder height and stature was highly significant; the coefficients of 0.73 between elbow height and stature and 0.67 between crotch height and stature were significant. The correlations of other measurements with stature were not significant—arm length with stature, r=0.45; hip height with stature, r=0.50; sitting height with stature, r=0.20. None of the girth measurements were correlated with stature.

Correlation of anthropometric measurements with energy expenditures showed no statistically significant relationships. The chest measurements of the women in this study showed no such correlation with energy expenditures as that reported by Seltzer and coworkers (*50*), who found that the chest circumference of 34 men was correlated with oxygen consumption in moderate exercise (r=0.817). Energy expended in walking with a load of 18 pounds at 120 steps per minute showed sizable negative correlation with length of leg (r=0.65) and with hip height (r=0.44), whereas the expenditure for walking without the load at the same pace showed low correlation with weight and leg length (r=0.26). The latter finding differs from that of Brockett and associates (*11*), who reported a highly significant correlation between leg length and energy cost of walking.

GENERAL COMMENTS

For comparison and recapitulation, data on basal metabolic rates and on energy expenditures at rest and for specific activities of nine women who were selected as subjects are summarized in the appendix (table 19, page 24).

Of the activities tested, the women expended the most energy when walking while carrying or pulling an 18-pound load and when performing a knee-bend with a 5-pound load.

Only a slight difference in energy expenditures was observed for subjects lying under basal conditions and while lying with no restrictions on the time elapsed after eating. Subjects 20, 43, and 44 expended more energy and subjects 31, 45, and 54 expended less energy for lying with no restrictions on food than they did under basal conditions. These six women expended a mean of 56.8 and 56.1 Calories per hour under the respective conditions.

This study was undertaken to serve as one basis for recommending energy-saving methods of performing household tasks, and to assist designers in developing housing facilities and arrangements of space and equipment that are efficient from the viewpoint of energy expended by homemakers. It is recognized that the energy cost of using equipment and household facilities is only one of the factors basic to good design. For example, information is also needed on the psychological aspects involved in the use of the equipment and facilities. Further study of more complex household activities is needed, both from the standpoint of physiological energy expenditure and of other factors contributing to fatigue.

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APPENDIX—BASAL METABOLIC RATE DETERMINATIONS

In table 15 are given the basal metabolic rates and data from other physical measurements for each of 68 women tested as one basis for selection of subjects who would meet the standards set up for the research. Individual metabolic rates varied widely, ranging from −44 to +53 percent. Ranges of age by decades are given in table 16, together with deviations from the commonly used "normal" of ±10 percent. The mean rate was −10 percent, the lower limit of this standard, and 54 percent of the women fell below that limit. These findings are in keeping with those of Leiner (*33*), who suggested that the DuBois-Boothby-Sandiford standard may be too high.

The effect of age on various physical chracteristics of the women studied is shown in table 17. Increases in weight, surface area, and blood pressure in the higher age decades are to be noted in columns b, c, and e; slight change in basal metabolic rate and total heat production in columns d, h, i, j, and k. The changes in pulse (f) and the relatively few changes in body temperature (g) are also noted.

In table 18 are shown data from basal metabolic rate determinations made over a 5-month and a 9-month period for two women, 21 and 22 years old. Considerable daily variation was found. These results agree with those reported by Benedict (*4*), Blunt and Dye (*6*), Griffith and coworkers (*25*), Hafkesbring and Collett (*26*), Kunde (*32*), and McKay (*38*). This study of basal metabolic rates may supplement other similar data as a basis for verifying presently used standards or perhaps developing new ones.

TABLE 15.—*Basal metabolic rate (BMR)*[1] *of 68 women 16 to 61 years of age*

Subject	Age	Trials [2]	Height	Weight	Surface area [1]	Energy expenditure		Deviation from selected standard for BMR	Blood pressure	Body temperature	Pulse
	Years	*Number*	*Cm.*	*Kg.*	*Sq. m.*	*Cal./hr.*	*Cal./hr./sq. m.*	*Percent*	*Mm. Hg.*	*°F.*	*Beats/min.*
1	16	2	163	57.3	1.594	60.0	37.6	−5.0	110/60	98.0	-------
2	18	2	163	58.6	1.608	66.8	41.5	11.0	120/70	96.5	60
3	20	2	169	53.9	1.594	55.0	34.5	−5.0	118/70	98.0	80
4	20	2	163	57.7	1.598	62.7	39.2	5.0	110/50	97.4	72
5	21	2	163	60.4	1.628	58.2	35.8	−3.0	110/60	98.8	80
6	[5] 21	3	170	62.7	1.711	54.9	32.1	−14.0	101/64	98.2	67
7	[4] 22	4	169	60.4	1.677	51.0	30.4	−19.0	102/64	98.1	67
8	23	3	173	55.0	1.636	48.9	29.9	−19.0	110/70	98.4	80
9	23	2	163	50.4	1.506	58.1	38.6	5.0	100/70	98.0	72
10	24	[3] 4	161	51.0	1.504	27.1	18.0	−44.0	90/40	97.2	70
11	24	2	159	67.1	1.681	59.9	35.6	−3.0	110/80	98.6	90
12	24	2	162	61.6	1.637	44.8	27.3	−27.0	92/64	97.6	63
13	26	2	171	63.9	1.726	59.8	34.6	−5.0	114/70	98.6	58
14	27	2	165	50.2	1.520	51.6	34.0	−8.0	108/70	98.4	72
15	28	2	164	62.6	1.652	48.6	29.4	−22.0	112/88	97.8	78
16	28	2	178	58.1	1.706	69.3	40.6	11.0	----------	-------	-------
17	28	2	165	53.6	1.568	36.0	23.0	−19.0	116/74	98.2	60
18	29	2	168	56.8	1.620	50.7	31.3	−16.0	92/60	98.0	82
19	29	2	146	44.1	1.350	33.1	24.5	−35.0	112/70	98.0	80
20	30	2	163	58.0	1.600	50.0	31.2	−15.0	115/80	98.0	84
21	30	2	164	56.4	1.594	48.5	30.4	−18.0	98/60	98.6	68
22	32	2	173	60.1	1.694	57.4	33.8	−7.0	110/70	98.4	68
23	32	2	160	62.7	1.632	55.7	34.1	−7.0	110/65	98.4	68
24	32	2	157	58.6	1.570	57.4	36.5	1.0	138/96	98.6	64
25	32	2	157	61.5	1.610	64.5	40.1	10.0	110/65	98.0	86
26	33	2	156	51.6	1.470	43.7	29.7	−18.0	90/68	98.2	64
27	34	2	157	77.7	1.774	52.7	29.7	−18.0	110/75	97.8	64
28	34	2	157	51.8	1.494	39.4	26.4	29.0	----------	98.6	80
29	34	[3] 4	164	58.0	1.622	52.2	32.2	−12.0	108/68	98.8	60
30	35	2	157	59.0	1.580	88.2	55.8	53.0	110/70	-------	72
31	35	2	161	64.0	1.660	52.8	31.8	−12.0	120/88	98.0	64
32	36	2	159	63.1	1.631	52.1	31.9	−12.0	116/84	97.8	74
33	37	2	178	68.6	1.836	66.2	36.0	−1.0	110/70	98.0	72
34	37	2	159	51.4	1.493	52.7	35.3	−4.0	110/70	98.3	80
35	38	2	154	56.8	1.536	25.9	16.8	−44.0	98/70	98.8	76
36	38	2	161	59.2	1.616	52.5	32.5	−12.0	114/70	97.8	52
37	39	2	163	61.5	1.640	51.5	31.4	−15.0	----------	98.0	100
38	39	2	160	47.7	1.460	57.1	39.1	7.0	120/75	98.2	70
39	39	2	160	57.7	1.578	82.2	52.1	42.0	100/70	97.8	82
40	39	2	163	57.2	1.594	51.8	32.5	−12.0	108/70	98.0	76
41	39	[3] 6	165	60.6	1.651	42.3	25.6	−29.0	120/74	98.7	78
42	40	2	163	58.4	1.602	47.7	29.8	−17.0	120/60	97.4	68

See footnotes at end of table, p. 22.

Table 15.—*Basal metabolic rate (BMR)*[1] *of 68 women 16 to 61 years of age*—Continued

Subject	Age	Trials [2]	Height	Weight	Surface area [1]	Energy expenditure		Deviation from selected standard for BMR	Blood pressure	Body temperature	Pulse
	Years	*Number*	*Cm.*	*Kg.*	*Sq. m.*	*Cal./hr.*	*Cal./hr./sq. m.*	*Percent*	*Mm. Hg.*	*°F.*	*Beats/min.*
43	40	[3] 4	162	63.4	1.658	53.1	32.0	−11.0	124/86	98.0	74
44	40	2	164	66.4	1.701	58.4	34.4	−6.0	108/88	98.6	96
45	40	[3] 4	163	69.2	1.734	62.7	36.2	0.0	------	------	56
46	41	2	159	56.5	1.570	51.8	33.0	−8.0	124/78	98.0	88
47	41	2	160	62.4	1.632	62.9	38.5	8.0	146/80	98.6	100
48	42	2	159	60.7	1.609	54.1	33.6	−6.0	100/60	97.2	56
49	45	2	160	56.3	1.564	47.8	30.6	−14.0	124/70	97.6	72
50	45	[3] 4	159	90.9	1.911	52.6	27.5	−22.0	132/80	98.4	76
51	40–50	2	170	60.7	1.694	60.6	35.8	0.0	100/70	97.6	76
52	45	2	157	71.2	1.704	44.9	26.4	−28.0	170/110	98.0	64
53	45	2	154	62.7	1.582	46.0	29.1	−20.0	132/76	97.8	68
54	46	2	161	59.3	1.600	59.8	37.4	3.0	110/78	------	80
55	48	2	164	68.3	1.720	49.1	28.5	−20.0	124/88	98.0	68
56	49	2	157	61.1	1.610	46.7	29.0	−20.0	134/80	97.8	80
57	51	2	164	73.1	1.766	51.0	28.9	−17.0	122/78	97.8	80
58	51	2	169	53.0	1.582	58.4	36.9	6.0	150/80	97.8	66
59	52	1	159	53.0	1.514	42.4	28.0	−20.0	120/80	------	------
60	53	2	165	65.0	1.700	53.9	31.7	−9.0	130/75	98.0	64
61	55	2	157	57.4	1.564	42.7	27.3	−23.0	112/80	98.0	80
62	55	2	162	54.7	1.555	43.4	27.9	−20.0	104/68	98.2	68
63	55	2	161	61.0	1.624	43.9	27.1	−23.0	148/90	------	76
64	55	2	168	61.0	1.674	53.7	32.1	−9.0	134/80	97.4	80
65	56	2	170	70.2	1.797	65.0	36.2	3.0	160/120	97.6	64
66	57	2	157	65.9	1.660	69.0	41.6	20.0	150/110	98.2	72
67	58	[6] 8	164	78.0	1.824	54.0	29.6	−14.0	158/96	97.7	60
68	61	2	166	74.1	1.808	53.3	29.5	−15.0	148/90	98.0	60

[1] According to the Aub-DuBois Standard as modified by Boothby and Sandiford (*7*).

[2] Average of trials occurring on the same day unless otherwise indicated.

[3] Subject returned for second day.

[4] Subject was tested on 21 days; see table 18.

[5] Subject was tested on 17 days; see table 18.

[6] Subject was tested on 4 days.

Table 16.—*Basal metabolic rates (BMR) of 68 women by age decades and deviation from standard*[1]

Age in years	Subjects tested	Tests	Deviation from selected standard for BMR		Subjects with BMR falling outside standard of ± 10			
			Mean	Range	Below	Above	Percentage of total number tested	
							Below	Above
	Number	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*	*Percent*
19 and below [2]	2	4	3	−5 to +11	0	1	0	1
20 to 29	17	110	−13	−44 to +11	9	1	13	1
30 to 39	22	50	−8	−44 to +53	13	2	19	3
40 to 49	15	36	−11	−28 to +8	8	0	12	0
50 to 59	11	27	−10	−23 to +20	6	1	9	1
60 and above [3]	1	2	−15	−15 to −14	1	0	1	0
All	68	229	−10	−44 to +53	38	6	54	8

[1] According to the Aub-DuBois standard as modified by Boothby and Sandiford (*7*).

[2] 16 and 18 years.

[3] 61 years.

Table 17.—*Certain mean physical characteristics of 65 women 20 to 58 years of age studied in the post absorptive state, according to age decades*

Age in years	Subjects studied	Height	Weight	Surface area	Deviation from selected standard for BMR[1]	Systolic blood pressure	Pulse rate	Oral temperature	Basal heat production			
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
	Number	*Cm.*	*Kg.*	*Sq. m.*	*Percent*	*Mm. Hg.*	*Beats per min.*	° *F.*	*Cal./sq. m./hr.*	*Cal./cm./24 hrs.*	*Cal./kg./24 hrs.*	*Cal./24 hrs.*
20 to 29	17	165.2	57.0	1.607	−13	106	73	98.1	31.7	7.44	21.54	1,228
30 to 39	22	161.2	59.2	1.606	−8	111	73	98.2	33.9	8.10	22.05	1,306
40 to 49	15	160.8	64.5	1.659	−11	125	75	97.9	32.1	7.94	19.80	1,277
50 to 59	11	163.3	62.9	1.660	−10	135	71	97.9	31.6	7.71	20.00	1,260

[1] Aub-DuBois standard as modified by Boothby and Sandiford (*7*).

Table 18.—*Basal metabolic rates (BMR) of two women as recorded over a 5- and a 9-month period*

Subject and date	Weight	Energy expenditure
Subject EA:[1]	*Kg.*	*Cal./hr.*
July 13	63.2	54.3
July 19	63.2	55.9
July 26	62.3	54.2
Aug. 2	63.2	47.1
Aug. 3	63.6	52.7
Aug. 9		53.1
Aug. 16	63.0	53.5
Aug. 23	63.6	50.8
Aug. 30	63.3	56.4
Sept. 7	63.6	56.4
Sept. 21	63.6	53.5
Oct. 4	64.1	56.1
Oct. 26		56.6
Nov. 9	62.0	61.4
Nov. 22	61.4	58.3
Dec. 6	60.6	58.4
Dec. 20	59.7	54.9
Mean	62.7	54.9
Subject BA:[2]		
July 13	61.1	52.9
July 19	60.8	50.2
July 26	60.3	46.4
Aug. 2	60.8	43.4
Aug. 3	60.8	49.0
Aug. 9	60.6	51.4
Aug. 16	60.9	48.1
Aug. 23	60.9	53.5
Aug. 30	61.4	51.2
Sept. 13	61.8	51.0
Sept. 27	62.3	48.7
Oct. 18		52.9
Nov. 1	60.6	34.0
Nov. 15	60.1	52.2
Nov. 29	59.2	49.9
Dec. 13	59.1	53.8
Dec. 17		56.3
Jan. 12	58.6	55.7
Jan. 24	59.1	55.9
Jan. 31	59.5	58.4
Mar. 31	59.7	55.3
Mean	60.4	51.0

[1] Age at first test, 21 years 7 months. Height, 170 cm.
[2] Age at date of first test, 22 years 1 month. Height, 169 cm.

TABLE 19.—*Summary of energy expenditures of nine women obtained under basal conditions and during test*

Subject No.	Height	Weight	Age	Energy expenditure [1]													
								Walking—								Trunk-bending with 5 lb. [3]	Knee-bending with 5 lb. [3]
				Under basal conditions	Lying	Sitting	Standing	At 96 steps per min.	At 108 steps per min.	At 120 steps per min.	At own gait	With 90° turns [2]	With 180° turns [2]	Carrying 18 lb. [3]	Pulling 18 lb. [3]		
	Inches	*Pounds*	*Years*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*	*Cal./hr.*
29	64.8	128	34	47.4										269.5	236.6		
44	64.8	146	40	58.4	59.5	70.5	71.3	140.2	146.9	153.5	143.0	153.8	153.2			188.1	220.4
20	64.0	128	30	50.0	56.7	50.1	66.9	138.1	146.7	160.3	162.4	179.3	174.6			179.2	219.6
45	64.0	152	40	62.7	59.1	61.5	64.8	157.6	156.9	165.9	170.9	169.5	191.0			180.0	224.4
43	63.8	140	40	53.1	59.3	68.1	67.5	148.4	158.0	175.1	186.0	175.4	167.2	291.3	290.6	173.1	265.2
31	63.5	141	35	52.8	49.5	52.7	57.3	128.4	135.8	144.9	138.6	146.3	153.7	256.7	238.0	137.7	188.6
54	63.5	139	46	59.8	56.5	62.7	67.8	131.8	133.6	153.5	168.6	152.5	159.6	274.1	266.0	181.2	227.5
23	63.0	138	32	45.1										266.8	268.0		
32	62.5	139	36	52.1										366.1	316.3		

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[1] Under basal conditions the McKesson Metabolar was used to measure the amount of oxygen consumed; basal metabolic determinations were made on dates preceding those of the activity determinations. For all other energy-expediture determinations the Müller-Franz apparatus was used to measure expired air and collect aliquot samples; oxygen content was determined by electronic analysis; measurements were made over a 2-year period.

[2] At 96 steps per minute.

[3] At 120 steps per minute.

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